Plant Improvement and Seed Production Project

CIRAD-Foret / ICSB joint project

OUTLINES FOR A RESEARCH PROGRAMME FOR THE ESTABLISHMENT OF A LARGE-SCALE PULPWOOD PLANTATION

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Background

This project constitutes a research support for an industrial tree plantation of 122,240 ha of *Acacia mangium*, its hybrids and related species, on an eight-year rotation. Based on an average out-turn of 144 m^3 solid-wood-under-bark/ha, this plantation will produce 2,200,000 m^3 per annum that will support the proposed pulp mill of 500,000 air-dry tons per annum.

Introduction

Given the scale of the programmed pulpwood tree plantation, there is a need to establish a strong research project[1] to support the operations and focusing on:

- the identification, selection and creation of new improved planting material;
- the establishment of appropriate technology for the mass-multiplication, the planting, the maintenance and the harvesting of this material;
- providing a continuous survey of the operations for the prompt identification of weak points, procedures that allow for improvement, and other traits such as pest and diseases, fertility management, etc.;
- providing continuous technology survey for taking advantage of any breakthrough made available by new techniques coming from the external world;
- providing staff training and instruction on the spot.

Sabah Softwood is already equipped with a research team, and since the early '80, a number of nursery and field trials have been established. The present planting operations are running quite smoothly, proving that the pioneer research work has been useful. However, an analysis of the existing set of experiments reveals that the information content of the trials is generally low, and that there is abundant scope for improvement both at the level of planting material and on the field techniques' side.

On the other side, the two ICSB/CIRAD-Foret joint projects[2] are equipped with research teams with a complementary experience in tree improvement and breeding, silviculture and vegetative propagation. The facilities at the Plant Biotech Laboratory will be particularly useful in fields such as tissue culture, use of micro-organisms (*Rhizobium* and *Micorhyzae*) and marker-aided selection and breeding. International links with CIRAD-Foret and other associated research institutions in France can bring a substantial support to the project where the competence is not present locally, such as in pulp and wood technology, pest and diseases management, mechanization, training, etc.

It is worth to notice that, financially, any improvement in actual volume production plays essentially on the plantation's marginal revenue, so that, in terms of percentages, it translates automatically in much more consistent economic gains. The increased gains largely repay the cost of research, provided the time between initiation of the research work and the outputs is not too long.

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[1] These outlines are only aimed at pointing out which matters need to be addressed by research in a large-scale planting programme; they do not engage in any way the responsibility or future work of CIRAD-Foret.

[2] Plant Improvement and Seed Production Project (PISP), and Plant Biotech Laboratory (PBL) – Tawau.

Our project is designed on the basis of two main characteristics: it is aimed for the **medium and long term**, so that the planting programme can be viable and competitive - against other similar plantations - for a considerable number of years, as it is needed by this type of operation; at the same time, it provides for **short-term** periodic outputs that allow to repay the cost of research without having to recapitalise for long periods. The main features of the project are summarised herebelow.

1. Species selection

While the main species of fast-growing forest trees for the planting programme have already been identified (*Acacia mangium*, *A. crassicarpa* and *A. mangium* x *auriculiformis* hybrids), it is still unclear which of the three is more suitable for pulp production or for site-specific planting. Comparative species trials of conventional and improved material of the three species will bring important information on their respective production rates, the pulpwood quality and other characters.

The project can facultatively explore the suitability of other species, such as other *Acacia* hybrids or the new varieties of *Eucalyptus* prepared for the humid regions of Africa (CIRAD-Foret). Further site-matching research can finely regulate the distribution of the species in the field according to the site characteristics.

2. Genetic improvement

Genetic improvement is the most important point to work on if the objective is to have continuous improvement along the years. The first step is to make a rapid assessment of the diversity and value of the genetic material already existing in Sabah Softwood.

2.1 Creation of new material

+ ***Generalities***

Based on this, a long-term progressive and recurrent selection/breeding strategy allowing for periodic outputs of improved varieties, can be established. The strategy, to be applied on the main *Acacia* groups, will resort to the use of: a) re-introduction of new genetic material if necessary; b) breeding of the existing or new genetic material both through open-pollination in clonal or family seed orchards, or through controlled pollination of trees selected in the progeny/clonal trials; c) establishment of trials comparing the new material obtained through breeding; d) periodic outputs of planting material obtained either by seed or by cloning the best families/individuals; e) new recombination of desirable characters through re-breeding along generations. The technique of controlled crosses, already available, should be improved in order to allow faster and easier breeding.

+ *Hybrids*

A special approach is needed for hybrids, the breeding of which will give very poor and variable material. Rather, the approach will consist of improving the two parental species separately, and then selecting the trees for their aptitude to the interspecific combining ability through interspecific breeding and hybrid family testing. In this case too, the approach will take in account a long-term improvement with periodical variety outputs.

+ *Periodic outputs*

For clarification, "periodic outputs" in our strategy for *Acacias* means: given one year for breeding and collection of new material, and three years for testing and full flowering, following the sexual reproduction pathway a new variety can be created in four years. The same holds true following the clonal pathway: three years for testing the clones plus one year for multiplication. The first seedlings/plantlets will be available at the end of year four, while sufficient material for mass planting will be available at year five.

+ *Gains*

Our preliminary analisys on existing *Acacia* trials indicated that, by this strategy, genetic gains of 5-20 % can be achieved at each of the first two-three generations of improvement[3], according to the breeding design (open *versus* controlled-pollination) and the selected trait (some traits will be easier to select for than others). The delay between periodic outputs can be shorter, but then the genetic gains will be smaller. Further gains may be pursued by searching for fortunate combinations of different *Acacia* species in hybridisation. Our economic calculations indicates that, in the present SSSB situation and given a log price of 85 RM per m^3, a genetic gain in volume of 10% would translate in an economic marginal surplus of around 25%.

2.2 Selection criteria

Selection criteria should be established in relation to the desired quality of the wood for pulp production. These will be defined in close relationship with the end user (pulp mill), but at present we can foresee the following important characters: volume, wood density, pulp yield and quality, resistance to diseases and ability to propagate vegetatively; other characters of stem form, while secondary to pulp production, remain important for facilitating the harvesting operation, the transportation, and the avoidance of wastage. Other elements as the efficiency in the use of the nutrients can be taken in account in a second phase, when the physiology of the species becomes better known.

2.3 Propagation of the planting material

Vegetative propagation is functional to the genetic improvement strategy, in order to allow the fast mobilization, rejuvenation and multiplication of trees with desirable characteristics. It can be useful at several stages: a) for the establishment of clonal trials or clonal seed orchard; b) establishment of hedge-plant parks designed for mass-propagation in the nursery; c) mass-propagation of planting material.

The whole technique of vegetative propagation will be addressed, with special focus on the use of in-vitro tissue culture techniques that allows the acceleration of the mobilization and rejuvenation stages. Other conventional techniques already available in SSSB such as marcotting (again for the mobilization of adult genotypes), conventional cuttings, grafting and hedge-plant management will be looked upon when necessary. Finally, the in-vitro and the conventional propagation techniques will be jointly employed to optimize the propagation rates while minimizing the costs.

2.4 Technology alertness

The project should also ensure a continuous technology wakefulness in order to take advantage of any appropriate breakthrough in new applicable methodologies. Special attention will be paid to the opportunity of building genetic maps for *Acacias*, with emphasis on a) the location of genes controlling the cellulose/lignin ratio and the lignin quality, for further marker-aided selection; and b) the genetic insertion / deletion of useful / detrimental genes. The facilities in the PBL in Tawau and its former involvement in a project of genetic transformation of *Acacia mangium* put it in an outstanding position for conducting this kind of research.

[3] Other examples are that, over the past twent years, an improvement in growth of 50% has been obtained for Teak in Ivory Coast, while even better gains were achieved in the same period for *Eucalyptus* in Congo.

3. Silviculture

3.1 Nursery and plantation practices

The proper use of improved material requires appropriate nursery and plantation practices, especially when dealing with large quantities. Potting media, containers, fertilisation, watering regimes, type (cuttings versus seedlings), age and size of the plants at planting, and culling are among the criteria to be finely regulated in the nursery. Transportation, site preparation and planting methods, spacing, fertilisation and maintenance are the elements that need to be addressed in the field.

3.2 Mechanization

With a large-scale plantation, it is worth to consider any possibility for mechanization. It can be applied all the way from the nursery to the plantation and harvesting stage. While the mechanization of the nursery is quite straightforward thanks to proved experience already tested elsewhere, the mechanization of the planting and harvesting operation need to be regulated in order to take in account the local site and socio-economic factors. For example, while in flat soils site preparation and planting can be done by tractor-mounted machines, on slopes it may be interesting to employ light man-carried devices. Mechanization of harvesting can, in addition to reduced costs, bring along a decrease of the wastage and of the soil disturbance.

3.3 Long-term management of the soil fertility

This is an important element of concern for the viability of the plantation in the long term. Not much is known on the effect of repeated forest tree rotations, however it is expected that fast growth and important biomass withdrawals at short intervals will deplete the nutrients in the soil at a fast rate. Reductions of down to 30% of production rates are recorded for second or third rotations of other tree species in other parts of the world. The fact that *Acacias* are nitrogen-fixing organisms may be positive for the nitrogen balance, but not for other mineral and organic elements.

A long-term survey of the fertility is then needed. At the first rotation, the simple observation and recording of the changes in the soil may be sufficient. From the second generation onward, combined studies of the soil modifications, the plant intakes and the growth rates can give several kind of outputs: apart from immediate information for fertilisation, they will also allow, on the long term, to define which species and which variety make better use of the nutrients available in the soil, so to optimise the energy transformation and the soil management.

3.4 Growth and volume tables

Growth and volume tables are already available for several *Acacia* species. However they are rather old and established on not-intensively managed stands. If the use of improved material and appropriate silviculture practices will bring as much improvement as it did for other species (50% for Teak in Ivory Coast and even more for *Eucalyptus* in Congo, etc.), there will be a need to establish new growth curves and volume tables adapted to the new varieties and techniques.

4. Pulp-wood technology

Research is needed in this field both to study the pulp characteristics of the species and varieties used in the field, and at the pulp mill level to improve the efficiency of the treatments. The involvement of a wood technology - biochemical laboratory such as the one available at CIRAD-Foret / France seems necessary to satisfy the requirements of this sector. Determination of characteristics such as density, fiber length, pulp yield, kappa number, strength, etc is also indispensable for the establishment of proper

5. Microbiological control

Symbioses

In several experiments conducted by CIRAD-Foret in various edaphic and ecological conditions, *Rhizobium* had a positive effect on the growth of *Acacia mangium*. Efficient strains have been identified, isolated and multiplied and are ready to be introduced in the field. Experiments on large-scale use of the inoculum and its persistence in the soil are however required for the present programme.

In much the same way, arbuscular *Micorhyzae* have induced an increase in growth in many forest tree species, and the common finding of the fungus on *Acacia mangium* encourages its systematic use in industrial plantations.

Both micro-organisms can be grown and inoculated easily using the same medium in the nursery. The PBL in Tawau has the facilities and the competence to carry out experiments and mass-inoculation, and can easily and usefully be involved in the programme.

Pests and diseases

By contrast, there is not to our knowledge enough expertise in Sabah to deal with pests and diseases such as the heart rot, the root disease and the rust attacking the *Acacias* groups on large-scale plantations. The involvement of specialised laboratories and expertise from abroad seems necessary for the good management of these problems.

6. Staff training

Staff training is indispensable both to transmit the new methodologies and techniques to the operation level, and to establish a common language between the more specialised research staff and the ground staff. In no other way the addressing of real field problems and their respective solutions can be managed, if not through common interests, tools and language. Staff training will concern the following field of expertise: mensuration, basic forest practices, pests and diseases identification, computer handling, basic statistics. Computer skill and basic statistics are needed at several levels (and not only by researchers) in order to keep proper records of the operations, and be able in the future to track back problems or information.

7. Research Management

Even if, for operations that needs a practical approach, it may not looks immediately obvious, proper planning and management of the human resource is a key element for the success of large-scale operations. The staff get trained by experience, and become more precious along its carrier in a specific place. This experience should be conserved ensuring to the staff stability and continuity, and incentives as training and career perspective.

The value of the human resource can be increased through proper collaboration and interaction with the external research world. In many cases, research collaboration brings multiplicative advantages to the participants in a win-win situation: for example, when a laboratory needs a field to test its new technologies, and a forest concessionaire is looking for new technologies to improve its performances. Finally, the experience accumulated in this way can be valued through the sale of consultancy and research services.